
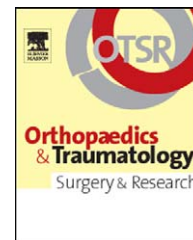




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ORIGINAL ARTICLE

Is alumina-on-alumina ceramic bearings total hip replacement the right choice in patients younger than 50 years of age? A 7- to 15-year follow-up study

P. Boyer^a, D. Hutten^b, P. Loriaut^a, V. Lestrat^a, C. Jeanrot^a, P. Massin^{a,*}

^a Department of Orthopaedic Surgery, Bichat Claude-Bernard Hospital, North Paris Teaching Hospitals Group Nord, Paris Diderot University, 46, rue Henri-Huchard, 75877 Paris cedex 18, France

^b Department of Orthopaedic Surgery, Rennes Teaching Hospital Center, 16, boulevard Bulgarie, BP 90347, 35203 Rennes cedex 2, France

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KEYWORDS

Alumina-on-alumina
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Patients younger than
50 years of age;
Long-term results;
Squeaking

Summary

Introduction: The alumina-on-alumina bearing couple in total hip replacement seems to be well adapted for young and active patients because of the absence of wear and the rarity of osteolysis. Over the long term, doubts persist as to the cementless cup fixation and on the functioning of this bearing system because of possible acoustic emissions during use.

Hypothesis: In young subjects, the ceramic-on-ceramic bearing system limits wear and osteolysis occurrences, without exposing patients to serious side effects.

Material and methods: We report the results, with between 7 and 15 years of follow-up, for 32 mm-diameter alumina-on-alumina implants in 76 patients younger than 50 years of age (83 hips), combining cementless press-fit hemispheric cups with titanium stems, [either cemented (63 OstealTM stems) or cementless (20 MulticôneTM stems)], with particular attention paid to cup fixation and noise emissions during implant function. First-generation or Cerafit trellisTM acetabular components had a riveted titanium mesh (31 cases), whereas the most recent (Cerafit hydroxyapatite [HA]TM) cups had a porous surface coated with hydroxyapatite (52 cases).

Results: Three cases of aseptic loosening of the cemented stems were observed as well as late migration of a Cerafit trellisTM cup in the 12th postoperative year. One ceramic insert broke in the eighth postoperative year. With the exception of one case, the patients, questioned retrospectively, reported no audible noise. With aseptic loosening (revised or not), the criterion for failure, the 12-year survival rate was $91 \pm 11\%$ for the Cerafit trellisTM acetabular components and $91 \pm 16\%$ for the cemented OstealTM stems. The 9- and 7-year survival rates for the Cerafit HATM cups and the MulticôneTM stems, respectively, were 100%. Including all revisions for any cause, the 10-year survival rate of the entire series was $92 \pm 11\%$.

* Corresponding author. Tel.: +33 0 1 40 25 75 03.
E-mail address: philippe.massin@bch.aphp.fr (P. Massin).

Discussion: Despite the absence of wear and osteolysis, the long-term survival of these implants in young subjects should be improved. Although longer follow-up is necessary to formulate a definitive opinion, we tend to prefer cementless stem and cup fixation in ceramic-on-ceramic bearing systems.

Level of evidence: Level 4 retrospective study.

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Introduction

Alumina-on-alumina total hip replacements have been used for several decades [1]. With this type of implant, the rate of osteolysis remains very low because of alumina's exceptional tribological properties, with low surface rugosity, producing a low-friction bearing system that generates very little or no debris resulting from wear [1–3]. These advantages are determinant when total hip replacement must be proposed to young patients. However, in the first series published by the promoters, the 10-year survival of the cemented alumina cups or the screw-fixed rings with an alumina core did not exceed 90% in patients younger than 40 and 30 years of age [4,5]. Subsequently, the use of impacted cementless acetabular components, with a titanium mesh coating (Cerafit treillis™), improved fixation, with a 98% 9-year survival rate [6]. However, in nonrevised cups, 38% showed a radiolucent line on the lower part of their fixation interface, and the survival of these cups beyond 10 years was not known with precision.

In addition, a few recent publications have brought attention to the suspicious noise frequently observed in patients with implants equipped with a Ceramic Biolox Forte™ cup (CeramTec AG, Plochingen, Germany) with 28 mm bearings [7]. This noise may be associated with microseparation of the implant components during walking, leading to peripheral wear of the insert (stripe wear) related to excentric friction of the bearing (edge-loading) [8]. Certain authors believe that this squeaking may be the precursor of insert rupture, which would compromise long-term survival [9].

We report the results of arthroplasties including cementless impacted hemispheric acetabular components with 32 mm-diameter bearings in alumina ceramic (CeraVer, Roissy, France) in 76 patients younger than 50 years of age (mean, 39 years) with between 7 and 15 years of follow-up. We examined the long-term results with particular attention paid to cup fixation and the existence of audible squeaking. Although the patients had indicated nothing during the prospective follow-up, we retrospectively sought to identify these suspicious noises for this study.

Material and methods

Patients

Seventy-six patients (83 hips) under the age of 50 were consecutively selected for an alumina-on-alumina arthroplasty because of their age (< 50 years), between September 1993 and September 2003 in our institution. According to the activity score described by Devane et al. [10], five patients were scored at 5 (active with no limitation on activity), 16 were Devane 4 (active), 33 Devane 3 (moderately

Table 1 Etiologies of the 83 arthroplasties in 76 patients (seven bilateral cases).

Osteonecrosis		45
Inflammatory		20
Rheumatoid	15	
Spondylarthritis	5	
Secondary arthritis		18
Dysplasia	7	
CDH (stage 1)	7	
Osteochondritis	4	
Total		83

CDH: Congenital dislocation of the hip.

active), 16 Devane 2 (semi sedentary), and six were Devane 1 (sedentary dependent). According to the Charnley score, 46 patients belonged to category A, 28 to category B, and two to category C. The main etiology was femoral head necrosis (Table 1) (45 hips), 22 with idiopathic necrosis, nine after corticosteroid therapy, nine post-traumatic, two cases of sickle cell anemia, two caused by alcohol intoxication, and one with HIV-related disease. The mean body mass index was 22 (range, 19–34) with three patients having a BMI over 30.

Material

All the implants were provided by the manufacturer (CeraVer). Two types of cementless impacted acetabular components were used: the first 31, called Cerafit treillis™ cups, were titanium cups coated with a fiber mesh (Fig. 1). Production of this cup was discontinued by the manufacturer in 1997 and it was replaced by a cup coated with porous titanium, which itself was coated with an 80 µm porous surface of hydroxyapatite (Cerafit HA™), used in the 52 most recent cups in this series. All cups were designed for peripheral impaction with a 1 mm equatorial rim.

These acetabular cups were combined with two types of femoral stem: all the stems were in titanium alloy, but the first were smooth and polished with an anodized surface so they could be cemented (63 Osteal™ cemented stems), whereas the more recent cups, available beginning in 2000, were coated with a porous hydroxyapatite surface and designed for cementless implantation (20 Multicône™ stems).

The friction bearing parts were in alumina (alumina ceramic; mean grain, 2.2 µm; density, 3.98). For the acetabular component, the insert was fixed in the cup by a 9 mm-deep Morse cone with a 5°42 slope. The cup chamfers were beveled to reduce any impingement with the femoral stem neck (Fig. 1c). As for the femoral component, the bear-

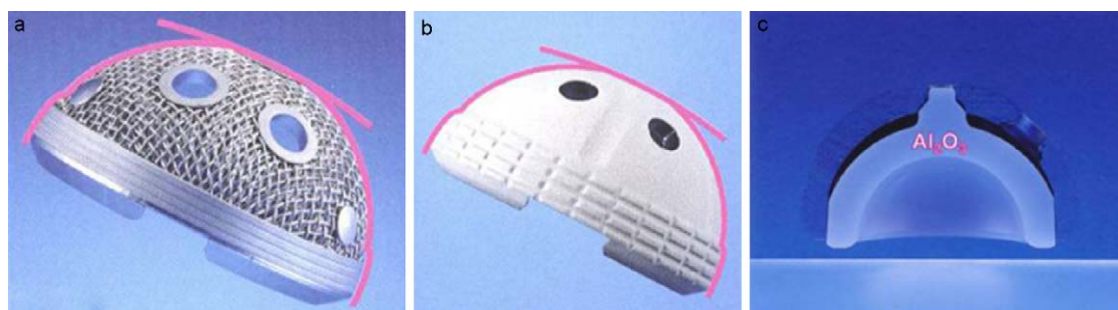


Figure 1 Acetabular cup models used in this series. a: Cerafit trellis™ cup with riveted titanium mesh. b: Cerafit HA™ cup coated with a layer of porous titanium and an 80 μm layer of hydroxyapatite. c: Detail of the interior aspect of the cup blocking the liner with a 9 mm-deep Morse cone.

ing was supported by a Morse 12 / 14 cone with a $5^\circ 42'$ slope. The implant neck was 13 mm wide and was smooth and polished.

Methods

Two senior surgeons (DH and PM) operated on the patients via a posterolateral approach. The acetabular cups were impacted choosing a size whose diameter was 2 mm greater than the last reamer size. Anteversion was guided by the bony contours while carefully avoiding the prominence of the edge of the cup, notably at the anterior wall of the acetabulum. Additional screw fixation was provided in only 10 cases (12%) because of insufficient hold after impaction. The smooth stems were cemented after obturating the diaphyseal canal and retrograde cementing using a syringe with canal drainage by aspiration. The hips were tested with trial implants in place in extension, external rotation and in flexion, internal rotation to verify that there was no intraprosthesis impingement in these two extreme positions.

Evaluation methods

The follow-up protocol included a consultation at 6 months, 1 year, and then every 2 years for clinical evaluation using the Merle d'Aubigné (PMA) score [11] and radiological follow-up. All the patients seen were questioned on the existence of noise coming from their hips that was audible to people around them. On the AP pelvic X-rays, cup inclination and stability were measured in relation to the acetabular lucent line on comparable X-rays according to the criteria established by Massin et al. [12]. The stem's vertical stability was assessed in relation to the vertical distance between the stem's shoulder and the top of the greater trochanter (corrected in relation to the enlargement calculated from the known diameter of the femoral bearing). Precise wear measurements were not possible because the contours of the ceramic bearing were not clear and they were superimposed on the radio-opaque cup, but the AP and lateral hip X-rays were examined searching for osteolysis. The rest of the radiographic examination consisted of the analysis of the cementing quality on the postoperative X-ray according to Barrack et al. [13] and looking for lucent lines in the seven femoral zones described by Gruen et al. [14] and the three

DeLee and Charnley [15] acetabular zones. Any ossifications were classified according to Brooker et al. [16].

Statistical analysis

Survival was studied using the Kaplan-Meier method [17] with 95% confidence intervals (twice the standard deviation). The failure criteria for survival were implant revision for any reason and aseptic loosening whether or not revision was performed, studied separately for the acetabular cups and the stems. The survival curves between the first- and second-generation implants were compared using the Haenszel-Mantel test [18].

Results

All patients were recontacted to be evaluated by an operator who was not their surgeon (PB). Except for one patient who had died from an intercurrent cause in the fourth postoperative year and six patients lost to follow-up in the first postoperative year, the 69 remaining patients (76 hips) had a complete clinical and radiological file. Logically, the first-generation implants were followed up over a longer period than the second-generation implants: 9.3 years (range, 9 months to 15 years) for the cemented Osteal™ stems versus 6 years (range, 11 months to 8 years) for the cementless Multicône™ stems, 10 years (range, 9 months to 15 years) for the Cerafit trellis™ cups versus 7 years (range, 9 months to 9 years) for the Cerafit HA™ cups. All the patients followed with their implants still in place had a documented follow-up ranging from 7 to 15 years (mean follow-up, 10 years).

There were seven implant failures in six patients (9.2%), with one patient undergoing repeated failure. Four patients underwent revision (one of them twice) to change the implants.

a) Three of these failures were aseptic loosening of cemented stems, which subsided more than 2 mm below the great trochanter (Fig. 2). The opposing cups, all first-generation cups (Cerafit trellis™), were stable, with no images suggesting osteolysis. One of the three patients underwent two revisions, the first time to change the stem after 6 years, then the second time for cup mobilization after 12 years, although the cup had been deemed stable and left in place at the first revision



Figure 2 Bilateral Cerafit trellis™ cup implantation in a 40-year-old female patient with rheumatoid arthritis. a: Preoperative condition. b: Postoperative X-ray of the same patient, right hip operated, showing an optimal aspect of the cement mantle. c: X-ray of the same patient 12 years later. During this time, she underwent THA on the contralateral side. Although the cups were stable, the right femoral stem was loosened, with 12 mm subsidence, and the patient was scheduled for revision.

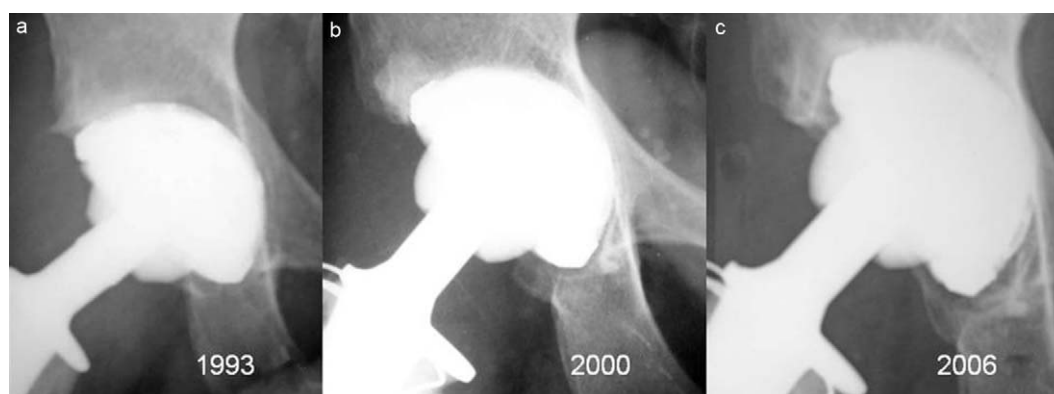


Figure 3 Cerafit trellis™ cup fixation. a: Postoperative X-rays of a 40-year-old male patient showing good cup position (42° inclination). b: Seven years later, during revision of the femoral component, the cup was tested and left in place. A radiolucent line is visible in zone 3, but the rest of the interface suggested bone anchoring. c: 13 years after implantation, the cup had verticalized progressively over 1 year but there was no osteolysis (the Cerafit trellis™ cup appeared to be broken in its lower part). The patient underwent revision elsewhere.

(Fig. 3). Two other cases of femoral loosening have not been revised to date despite the stems sinking more than 2 mm, because the symptoms remain moderate, limited to painless limping (Fig. 2).

- b) Another failure was related to ceramic insert rupture in the Cerafit HA™ cup during the eighth postoperative year. In this patient, there was no precursor of suspicious noise or trauma. Cup inclination was 25° . During revision, both components were found to be stable, with bone anchoring of the cup. No traces of impingement were found on the prosthesis neck, as feared given the cup's horizontal position.
- c) Finally, two patients had to be reoperated, one for recurrent dislocations and the other for deep infection of the surgical site. In the first case, only the cup was changed and replaced with a dual mobility cup. In the second case, the entire prosthesis was changed in two stages during the second postoperative year. These two acetabular cups, both Cerafit trellis™, also showed solid bone ingrowth.

In the 63 remaining patients (70 hips) with the implants still in place, there were a few complications that did not require changing the prosthetic components: one periprosthetic fracture fixed with a plate in the second postoperative year that showed bone union in 3 months (1.3%), one case of

regressive sciatic paralysis (1.3%), and two early dislocations that have not recurred to date (2.6%).

The results of the 72 nonrevised hips (65 patients) are provided in Table 2 and were very good or good apart from two cases of femoral loosening that were not revised. The mean preoperative PMA score was 11 ± 2.4 points (range, 7–13 points) and evolved to 17 ± 1.7 points (range, 12–18) at the last follow-up. For the cases of osteonecrosis, the mean preoperative mobility score was 4.8 ± 1.6 points, increasing to 5.7 ± 0.8 points at the last follow-up. During follow-up, none of the patients indicated bothersome noise coming from the hip. At the current review, questioned on this possibility, none could remember the occurrence of this phenomenon except one patient who indicated squeak-

Table 2 Clinical results at last follow-up in 65 patients (72 hips) with more than 7 years of follow-up and implants still in place (including nonrevised cases of loosening).

Merle d'Aubigné score	Preoperative	Last follow-up
Poor	72	2
Fair	0	2
Good	0	23
Excellent	0	45

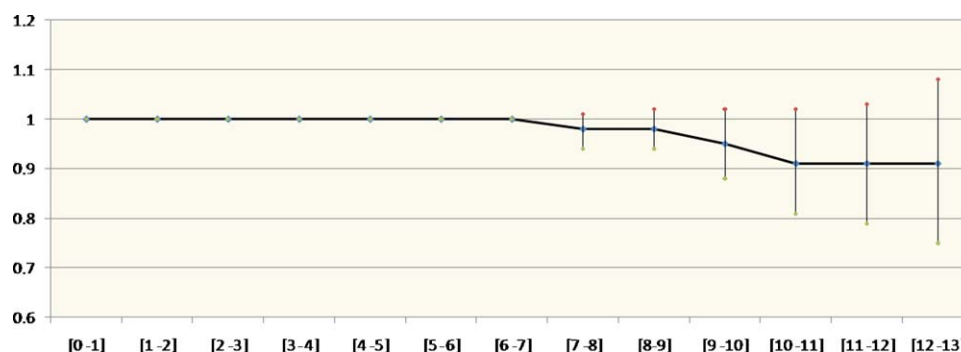


Figure 4 Survival curve of the cemented Osteal™ stems with confidence interval. The failure criterion was aseptic stem loosening, whether or not it was revised (cumulated 10-year survival rate: $91 \pm 10\%$).

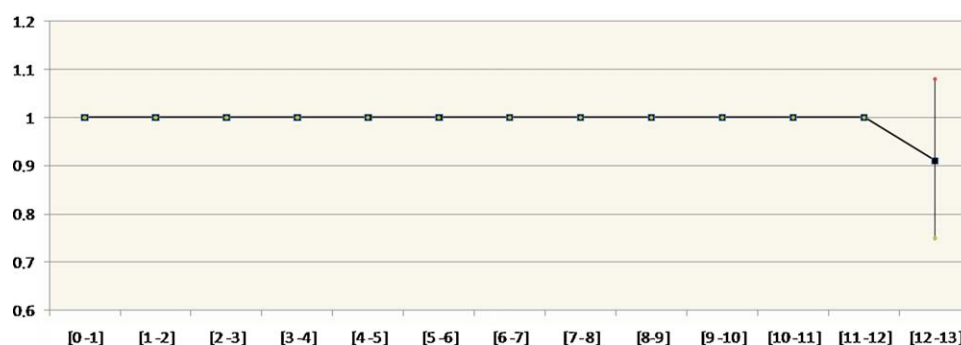


Figure 5 Survival curve of the Cerafit trellis™ cups with confidence interval. The failure criterion was aseptic cup loosening, whether or not it was revised (cumulated 10-year survival rate: 100%).

ing when walking, lasting approximately 1 year during the second postoperative year, before its spontaneous disappearance, with now 7 years of follow-up. The cup inclination in this case was 40° .

Radiologically, the mean cup inclination was 39° , ranging from 25 to 51° . In 12 cases, a fine radiolucent line developed in DeLee and Charnley zone III, but it remained stable after 2 years. The femoral stems appeared stable except the two cases of femoral loosening with 2 and 12 mm of sinking. The aspect of the cement mantle was optimal according to the criteria of Barrack et al. [13] on the postoperative X-ray, including the case of later femoral loosening (Fig. 2). At the last follow-up, apart from the two cases of nonrevised femoral loosening with circumferential radiolucent lines at the cement–bone interface, there were no radiolucent lines at the prosthesis–cement interface or the cement–bone interface. There were no radiolucent lines at the prosthesis–bone interface in the cases of cementless implants. There was no osteolysis on the plain images. The ossifications were scored 1 according to Brooker in 62 cases, 2 in eight cases, and 2 in two cases.

The 10-year overall survival rate, considering failure to be revision for any cause, was $92 \pm 11\%$. The 12-year survival rate of the Osteal™ cemented stem fixation (whether or not aseptic loosening was revised) was $91 \pm 16\%$ (Fig. 4) and $91 \pm 11\%$ for the Cerafit trellis™ cups (Fig. 5). The 9- and 7-year survival rates for the cementless Multicône™ stems and the Cerafit HA™ cups, respectively, was 100%, but the difference with the first-generation cups did not appear sig-

nificant at this stage with the numbers of patients in the series ($p = 0.2$ and 0.3 , respectively).

Discussion

These results do not challenge the tribological properties of alumina, since no osteolysis was detected, knowing that plain radiographs have only 64% sensitivity for osteolyses greater than 10 mm^3 [19]. However, even based on plain X-rays, these results are better than what can be observed with conventional polyethylene cups in this age group (20% osteolysis at the intermediate term in patients younger than 50 years of age [20]). Bonnomet and Glorion's recommendations [21] for hip arthroplasties in patients under 30 also show the same tendency, because the wear rates observed in this population are much lower (nonmeasurable) with hard-on-hard cups, whether metal-on-metal or alumina-on-alumina, than what has been observed with cups including polyethylene. As for cup fixation, the only failure (late) decreases their 12-year survival rate to 91%, which clearly shows that long-term follow-up is necessary to guarantee bone–cup fixation. However, the three cases of aseptic loosening of cemented stems are more worrisome. In a non-selected population, the promoters had reported an 87% 20-year survival rate with this stem [1], and then more recently 100% at 9 years in patients less than 55 years old [6]. Yet, in the series reported by Rousseau et al. [22], a few cases of long-term femoral loosening with the same femoral implant and the same friction bearing were also

observed (2.8%). Our results in younger patients suggest that the cemented fixation is not necessarily the best choice with ceramic-on-ceramic acetabular cups. In the absence of osteolysis, the source of loosening seems purely mechanical. Excessive solicitation of the cement sheath by the loaded deformation of the titanium implants with low modulus of elasticity can be put forward, as Huiskes's finite element studies [23] suggest. Cementless fixation, which we prefer, needs to be validated by longer-term follow-up. Finally, several complications, some related to alumina, can compromise implant survival in these young and active patients. The dislocation rate (3.9%) is by no means insignificant, despite the use of a 32 mm head, and is undoubtedly related to the posterior approach. In the series reported by Bizot et al. [6] with the same type of implant in patients less than 55 years of age operated on via the posterior approach, there were also a few cases of dislocation (2.8%). The 10-year survival rate ($92 \pm 11\%$) remains lower than the 100% rate in a population of the same age that had received cementless implants with a metal-on-metal bearing [24].

We observed no noise in this population with this prosthesis. One of the hypotheses that could explain this squeaking, when present, involves abnormally high friction in certain weightbearing conditions, causing cup vibration [8]. The transmission of vibrations may depend on the fixation of the core in the metal cup. In particular, micromovements of the insert may amplify this phenomenon. In this prosthesis, the core is joined to the cup with a $5^\circ 42'$ Morse cone, which is not the case in the other series reporting audible phenomena [7]. In their finite element study, Walter et al. [8] modeled core/cup interlocking with an 18° slope, which would allow loaded micromovements on the order of $40 \mu\text{m}$ between the two components for cup anteversion greater than 40° .

Alumina insert fracture is a rarer complication than bearing fracture, found in the large series reported in the literature [6,25]. Overall, Hannouche et al. [26] estimated the risk of rupture of one of the components at 1/7000. With today's ceramics, this type of complication should only occur in certain predisposing conditions: overly vertical cup orientation [27], imperfect interlocking of the bearing or the insert on its Morse cone, or intraprostatic impingement between the alumina and the stem neck. As for the insertion of the insert in the cup, the height of the Morse cone plays an important role in guiding impaction (here 9 mm for the cup). When the Morse cone is insufficiently deep, asymmetrical interlocking can be feared, causing excessive stresses on the periphery of the alumina core [28]. Rupture of the alumina insert should therefore be interpreted in relation to the interior design of the metal cup. On more recent cups, this depth has been increased to 11 mm. The microseparation of the friction surfaces during the suspended phase of gait can also cause edge-loading during the return to the weightbearing phase [8]. This microseparation may be facilitated by capsular laxity and can be suspected in patients who have experienced dislocation. In the present series, the two early dislocations had no later consequences. Finally, intraprostatic impingement is less frequent with large-diameter femoral heads [29] but, although it is exceptional with 36 mm heads, it remains possible but unlikely with 32 mm heads if the cup is properly oriented.

This study has a few limitations, in particular the retrospective nature of the study on squeaking. However, this is a

recent source of worry, which was not raised at the time the prospective inclusion, and was not indicated by our patients. There is also the problem of the few patients lost to follow-up. Since they had moved for job-related reasons, they did not report after their 1st year after implantation but their last radiological and clinical work-up was excellent.

Keeping these limitations in mind, it seems that the long-term success of the ceramic-on-ceramic cup implants depends on a number of parameters such as the cup design, the diameter of the femoral bearing, and the precision of the surgical technique. With the latest-generation implants used in this series, whose fixation is reliable at the intermediate term, follow-up beyond 10 years remains unknown. Other options such as metal-on-metal cups or reticulated polyethylene remain open but have already shown their limits (stripe wear, intraprostatic impingement, hypersensitivity), which can become a source of osteolysis [30–33]. Recent progress has again improved the reliability of ceramics (inclusion of strontium and zirconium grains in the delta ceramic), which therefore remains a good tribologic choice in young patients.

Conflict of interest statement

None.

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